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PRELIMINARY SPECIFICATION OF A TRUCK/SHOVEL OPERATING AND MANAGEMENT SYSTEM

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PRELIMINARY SPECIFICATION OF A TRUCK/SHOVEL
OPERATING AND MANAGEMENT SYSTEM

by

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ABSTRACT

In this report, the general structure of an operating and management system for the truck and shovel operation at surface mines in Canada is proposed. The proposal is from the point of the users : mining engineer, foreman, dispatcher and mine manager. The specifications and system operations requirements were solicited from the potential users at various mine sites in Western Canada, by study of existing models and through literature search.

The proposal is not rigid in its requirement. It may and probably will be modified by the software developer, during the validation process and ultimately by the user.

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SPÉCIFICATIONS PRÉLIMINAIRES D'UN SYSTÈME D'EXPLOITATION ET DE GESTION POUR UN CAMION-PELLE

par

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RÉSUMÉ

Dans le présent rapport, on propose la structure générale d'un système d'exploitation et de gestion pour l'ensemble camion-pelle à pelle dans les mines à ciel ouvert au Canada. La structure proposée a été élaborée en fonction des utilisateurs, c'est-à-dire les ingénieurs des mines, les contre-maîtres, les répartiteurs et les gestionnaires des mines. On a demandé aux utilisateurs potentiels dans diverses mines de l'Ouest canadien de définir les spécifications et les exigences relatives à l'exploitation du système à l'aide d'une étude des modèles existants et d'une recherche documentaire.

Les exigences de cette proposition ne sont pas rigides. Elles peuvent être modifiées, et le seront probablement, par le concepteur du logiciel, durant le processus de validation et, enfin, par l'utilisateur.

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INTRODUCTION

Truck haulage is the most widely used but also the most expensive means of transportation in a surface mining system. It was recognized by several mining experts that the truck-fleet productivity in surface mines has the lowest improvement rate among the three major unit operations: drilling, loading, hauling (1). Trucks require much labour, high maintenance and relatively frequent replacement, making them sensitive to inflation.

Most operating shovels experience either insufficient or excessive truck capacity or a combination of both. To meet the required production with increased overburden/coal ratio in newly expanded mines, new equipment is required each year. Management is faced with the problem of buying additional trucks and shovels if there is improper balance of equipment in the mining operation.

The problem of balance of equipment in the mining operation usually results from inadequate use of haulage resources, insufficient maintenance procedures, or poor management. Recent reduction in the price of coal on the world market and ever increasing labour cost, will further put pressure on mine operator to cut its unit production cost. The mine operator will therefore look for the means and strategy for optimizing truck-fleet production.

Several deterministic and event-based models to help mine engineers with optimization of mine haulage systems exist. Truck manufacturing companies provide optimization studies for mine operators free of charge. Each manufacturer will propose its own fleet of the equipment as the best available and also best suitable for the mining operation in question. Several software consulting companies will propose their optimization system software, from simple haulage design calculation to overall dispatch system. The mine operator has the choice: to accept outside advice and see what may happen, or investigate all available systems on his own. The choice that is made is often not the solution to the problem, because compromises are made

to have the system working as soon as possible, or to have an acceptable solution before deadlines imposed by upper management.

It was identified by mine engineers from several mining companies in Canada, that what is needed is a simple truck and shovel optimization program, that will be easy to use without advanced computer expertise, that will be able to monitor mine haulage systems and provide answers to the user at will. The mine operators are not looking for large and expensive systems, but will gladly accept advanced systems if the cost is in the budgeted limit. They prefer to have the system designed in house, because they feel they can produce systems that best suit their requirements. On the other hand, mining companies often lack people and resources to complete the task on their own. This is where research organizations, such as CANMET or NRC, may provide valuable service to the industry: by co-operating with them in designing the modelling tool that will suit industry requirements.

The state-of-the-art in computing technology has advanced to the point where there are several truck optimization models, several truck dispatching systems, and several truck management, data collection systems, that may be used in combination or on its own right now. Truck dispatching systems in the mining industry can solve the problem of inefficient use of resources by reducing waiting times in the haulage operation. Several mining companies has implemented dispatching systems in their operations. The ultimate question, of course, is whether the savings warrant the cost of such systems, or if the mining company has use for all the information provided by the system.

The proposed development of the event-based modelling aid may provide the long awaited answer to the mine optimization problem. What is proposed is a general mine model, that may be used by any mining company without extensive modification or prolonged training. The model will use existing technology, but will be flexible enough to accept changes in the future. The model will be part of the overall mine optimization program, will accept real data generated on site, will update itself by using these data and will provide the mine with a simulation modelling tool to predict and solve events that may arise in the future. The proposed interface between model

and its user will be designed in the way that mine manager, engineer, foreman, equipment operator, will find his own answer without being "buried" in unwanted information.

SIMULATION STUDY PROPOSAL

The effect of implementing the truck/shovel optimization system in the mining operation will be jointly studied by the mining company engineer and software developer. It is recognized, that computer simulation is the best tool that can be used now to predict changes in system behavior for any contemplated changes to the existing system. The proposal when implemented will also help to study the impact on mine productivity by employing the truck/shovel system for data collection, dispatching policies and simulation of the processes.

The following program modules will exist:

1. Stochastic model of truck/shovel system.

The model will use statistical distribution of the time values as input. This may be derived in a variety of ways. The model will support dispatching algorithmus.

2. Travel time simulation.

This module will derive truck time distribution from on-board data collection system and from haulage characteristics and serve as an input for the stochastic model.

3. Optimization module.

A program that will determine the optimum truck allocation based on minimizing of truck delay times, shovel delay times, etc.

4. Graphics module.

A graphics module will be used to display data derived by simulation or measured in the field. Where real time data acquisition system is used, real time display will be created.

5. Data management module.

This program will manage the data files by keeping track of what is already known for both simulation and data acquisition.

6. Maintenance module.

The module will provide user interface for maintenance department, to keep track of equipment usage, components used, service performed, preventive maintenance work, and similar statistical data.

7. Real time data acquisition interface.

This communication module will be pre-programmed to interface other modules with devices for data collection used at the mines, such as OBDAS, Modular Mining Dispatch, etc.

8. Data entering/editing system.

It will be used to enter for example time study data and perform the necessary computing functions to extract time distribution parameters, etc.

9. Dispatch module.

It will be used to dispatch trucks to loading points according to dispatching policies at the mine.

10. Automatic vehicle location module.

This module, using other models, such as route map and digital terrain models, will be used for vehicle positioning and real time optimization and scheduling.

General Steps in the Simulation.

To achieve results in any simulation study, the following basic tasks should be performed:

1. Determine the problem,
2. Build a simulation program to address the problem, and
3. Use the simulation program to solve the problem.

In Task one, the analyst is employed. He must understand the problem and must find the mathematical solution to the problem under consideration. System analysis of a truck/shovel mining operation is far too complex to be conducted by the analyst alone. The user (mine engineer or mine manager) must co-operate with the researchers. This problem is recognized in this report.

Task two, consisting of building and programming a truck/shovel simulation model, is proposed to be performed jointly by the analyst and user. The user may be represented at this stage by Canmet, who is familiar with requirements of mining industry. It is proposed to develop this Task in segments or modules, that may be used independently and may therefore be tested in the field. This approach demands communication between analyst and user.

The main emphasis in model development will be placed on Task three. Firstly, the model will be tested using real data supplied by the mining company and CANMET (using their previous studies). The test case will be developed jointly between users, if more than one mining company is co-operating in the project. Two different systems of control-with and without dispatching-will be tested. It is expected that the mine that is

directly involved in system development will have some kind of data collection and management system in place and operating. The real data collection system will be firstly tested in a non-dispatching mode, sometimes called "rigid" truck assignment mode, where trucks are "locked" to shovels during the entire shift, and events are simulated. The changes required in this first approach will be identified and noted. Alternative to this system operation will be a test run in dispatching mode, where trucks will be allowed to serve different operating shovels through the entire shift. A comparative study of idle equipment between both modes will also be performed. The dispatching system must be able to update itself using previously collected data. It is proposed that the updating will not be done continuously, but instead, for example, monthly statistical distribution may be used to project future occurrences. The updating time selection will be user defined.

Data Collection and Evaluation.

The operating and production data needed for the study were already obtained and evaluated. It is proposed to use these data to develop the structure of the model and define specifications. Later on, these data may be updated by time study, when the user's requirement will be more closely defined. The data collection devices, previously tested at various mines (2, 3, 4, 5) will be used to collect data for validation. As a minimum, the following data will be collected:

1. Haulage road profiles and characteristics such as distances, grades, rolling resistances, efficiencies, speed limits, assignment policies.
2. Equipment data characteristics and availabilities, including speed-rimpull curves, retarder curves, mechanical availabilities, and so on.
3. Shovel's time observation data, such as loading and dumping times, bucket loading factors, load weights, etc.
4. Other relevant information, pit configuration, equipment location or any other associated production data expected to be needed for simulation.

It may also be possible to use some proprietary data supplied by the mining company on the understanding that data may be used for validation purposes only, or to illustrate mining activity, but it will not be disclosed to a third party. The historical data on mine production, availability of equipment and efficiency data may as well fit into this category.

The developed model must be able to collect the raw data necessary to determine the location and function of the haulage trucks. This may be accomplished by using direct data gathering devices, such as OBDAS data gathering system presently being tested at Gregg River mine in Hinton, Alberta, or data transfer devices using the telemetry system presently being tested at Syncrude mine in Ft. McMurray, Alberta. Any other system may be applicable and the developed model must provide means to interface with various data collection systems. It is expected, that data collection systems required for the interfacing, will be identified before commencement of the work on the event-based model.

The data collected will include the following information as a minimum:

1. Payload hauled per load cycle.
2. Haul cycle time segments, including:
 - time to load,
 - loaded time to dump,
 - time to dump load,
 - return time to be loaded, and
 - an identification of all other haul cycle time segments.
3. Details of truck operation including:
 - vehicle speed,
 - roadway inclination and elevation,
 - gear in use,
 - gear changes,
 - rate of fuel consumption,
 - TKPH rate,
 - vehicle direction (forward/reverse), and
 - time and date.

The data elements will be manipulated by the program to provide both averages and statistical distribution for different time segments, totals, trends and other relevant data manipulation for performance analysis. The use of the data and time frame for analysis will be defined by user. This therefore must be a user defined event. The program will analyse obtained data for their respective distribution, so the data may be ready to be used for later updating of monitored events. The following are examples of data that may be analysed:

- shovel loading time,
- truck dumping time,
- loaded weight and its distribution in truck,
- quantities of material hauled,
- generation of travel times,
- TKPH data for each truck and time,
- haul road profiles,
- availability and utilization of equipment, and
- tonnages hauled and remaining in place.

Data collected or generated will be periodically transferred to the main computer for processing. The processed data will be used for study of assignment policies, optimization of equipment and mining processes study or simply for reporting purposes. The user will determine its intention on utilization of all data collected.

Problem Discussion.

Ideally, the model should be developed by direct concentrated effort of the mine engineer who will define its requirement, the computer analyst who will design software, and the user who will use the model and be happy with what the model will provide. This is not the case in real world. Based on the previous experience, the user may or may not be identified at the development stage. The mine engineer has a general idea what he wants at the

beginning, but his requirement changes as he learns more about the model and after his consultation with the user and computer analyst.

First model developed is usually the raw model that will give the user an idea what the other parties are proposing. This is the time, when the first hard look on model must be done by all parties. The analyst will then incorporate suggestions into the model, or propose alternative solutions. It is proposed, these first time discussions must be made a maximum two to three months after work commenced. The user may lose interest if he is not periodically consulted or informed about progress. This consultation may also prevent the analyst from going too far in the development stage without feedback. The future user must therefore be clearly identified, because he is the key person to the success at this stage. All parties participating in the development must develop plans and must adhere to the schedule. The extend of the simulation program must be clearly defined. Changes are quite possible in the future, but these changes must be in the same field. If, for example, the user defines his requirement for a truck/shovel haulage simulation program, he must expect to have this program only, and not ask for a different program. He may however suggest its future requirement, so the analyst may make provisions in the present model structure for an expansion of the present program at a later date.

The requirement in this proposal is defined as follows:

1. Optimization of truck/shovel operation at selected surface coal mines in Canada.
2. Design tool for planning for optimization of the mining system while meeting production objectives.
3. Provide planning aid to allocation of existing equipment, while providing assessment of present situation or future requirements.
4. Provide assistance to the mine management in dispatching policies, based on previous experience and data collected and analysed.
5. Display location of the monitored equipment in the mine and provide user with the status report of all equipment.

6. Provide periodic or on demand reports on data collected, mine productivity, equipment utilization and availability, delay times, or any other defined information.
7. Serve as a planning aid for expansion of the existing mine, or for prediction of future needs (capital investment, maintenance requirement, major repairs scheduling).
8. Provide time critical information for decision making.
9. Help to maintain steady production of material of uniform quality for processing.
10. Improve safety through better and faster communication by identifying problems that may happen in time.

The proposed model will address these requirements by performing the following functions:

1. Non-operator dependent collection and storing of data.
2. Manipulation of data to define existing operational characteristics.
3. Making decisions based on collected or supplied data.
4. Displaying information for user interaction.
5. Providing user-friendly access to the data for various management control functions.
6. Providing access to the data base for updating or specified manipulation.
7. Provide comprehensive printed reports.
8. Provide means to change, expand or modify the system to meet additional requirements

PRELIMINARY MODEL SPECIFICATION

Identification of Needs.

A studies of the problems associated with utilization of mine equipment (6, 7, 8) indicated several problems that could be sucessfully addressed by the simulation model. The most frequently applied way to allocate trucks to shovels or other loading equipment is to use the dispatcher's best judgement. His previous experience may or may not warrant his judgement. The dispatcher keeps track of which trucks are assigned to which shovels by simply noting the truck numbers down, or by lining up numbered trucks markers on a board based on shovel assignments.

Two major problems may be encountered by this manual dispatching: Firstly, it is difficult for the dispatcher to allocate the trucks in such a way that truck delays at the shovels and shovel waiting times are minimized; and secondly, it is impossible to follow up on drivers to make sure they completed their assignments promptly and reported in for new assignments when they should have.

Manual truck dispatching must be directly supervised by foremen and other supervisory personel - increasing overhead cost. This may be possible in small operations, where foreman can overview the operation on a regular basis. In large operations, this direct supervision is not feasible. Manual dispatching may also not solve the problem. Addition of other requirements to the simple truck allocation, such as blending, may present problems, that even the most reliable dispatcher is not able to solve.

One of the most pressing needs that mine simulation programs should address is direct monitoring of the haulage system. This monitoring as a basic rule must include:

- calculation of round times,
- calculation of average distances,
- calculation of speed variances,
- calculation of quantities and qualities of material hauled,
- identification of delay and queuing times,
- simulation of truck and shovel performance,
- identifying road surface problems, and
- simulating equipment breakdowns and its frequencies.

A second need identified for the model is to provide assistance to management in the following areas:

- reducing shovel idle times,
- reducing truck queue times,
- reducing the effect of disruptions caused by equipment breakdowns,
- helping to maintain proper record of processed events,
- helping to maintain consistent blend of material for processing,
- providing time-critical information for decision making, and
- improving safety through better communication.

Strategies of Modelling.

The following applications of the model are proposed to be tested in field to develop "best strategy" approach in modelling:

1. Fixed shovel allocation.

This is the simplest case. All truck not having problems (breakdowns, etc.) are assigned to one of the shovels according to the short term production schedule. If a breakdown occurs during the shift, this shovel will be undertrucked for its duration, the production from this shovel will be behind schedule. If there is a shovel breakdown, all trucks assigned to this shovel will be idle for this period.

2. Allocation of available trucks to replace assigned trucks.

This strategy is an improvement to the fixed shovel allocation schedule. The trucks that become available during the shift are assigned to replace those, which have failed. This may be done according to the sequence of truck failures or according to relative arrears of the shovels.

3. Allocation of trucks to shovels which have the greatest need.

Each truck which has been unloaded will be assigned to the shovel which has the greatest need for it, taking into account the likely situation at that time when this truck is expected to arrive at the shovel.

Manual dispatching may solve the problems of the first two allocations. However, automated dispatching will provide us with the data needed to compare the first two cases with case three. This last case requires computer based aid to address and solve the problem. There are number of variables that may be included in the approach. Also, extrapolation of the situation at the time of decision making for all shovels must be checked, if truck allocation is based on time of arrival at the shovel. This allocation may be rechecked and altered if necessary. In addition to computerized data collection and evaluation, the transmission of data for processing must be addressed.

It is recognized, that strategies for truck assignment will vary from one property to others. Some variances were identified in previous studies (9 - 17), some will be identified later. It appears, that numerical results that are applicable to one mine, are not necessary applicable at other mines, even if conditions looks somewhat similar. The similarity must be identified, so the procedure for development of the model for other mines will not be repeated. Generally, the more complicated the dispatching strategy the more closely the mine situation may be monitored or described. However, complicated dispatching systems are not always user friendly and therefore are not used by the people that can benefit from it the most: first line supervisors and mine managers.

The proposed model must be able to answer and identify problem fast. It may provide "Optimum solution" to the problem, but "Best strategy" may be achieved at any specific operation. Another questions that may be asked by the user may include "What is the optimal fleet size for a given operation" and "What will be the likely effect of technical changes". This may include introduction of new types of trucks, shovels or other loading equipment, haulage improvements, increasing speed of the trucks by improving engine performance or, for example, by trolley assisted uphill driving, etc.

Several methods of allocation of trucks to the loading equipment may be tested. The truck fleet requirements can be established by testing the vehicle fleet for "match" or "mis-match" factors. It must be recognized, that no equipment is 100 % utilized at any time. This, together with the random nature of truck arrival, reduces the potential of this method.

It is difficult to ascertain any significant benefit of the simulation program at the present time. Generally, if benefit to introduce this approach must firstly be proved to the mine operator, the system has no chance for survival. The mine operator will not likely co-operate on development of the program, and will not use it even when become available. Development of simulation models involves extensive analysis into the detail of load-haul-dump cycles on one hand. On the other hand it is very difficult to incorporate all such details into a practical computer program. The best possible approach is to develop step-by-step strategy, presenting partially developed modules one at the time, so the user become acquainted with the model slowly and he feels like a developer of the model at the same time.

Formulation of Requirements.

The primary objective of a control system will be to order truck movements to limit truck waiting time at the shovels and ensure that the quantities of material loaded from the qualities described in areas of the pit are maintained in strict ratios to meet the predetermined tonnage and blend requirement. The secondary objective must assure that maximum waste material is hauled from various pit areas in an order of priorities established by mine planning engineers to meet predetermined coal/waste stripping ratios.

The premises that may be adopted for the truck control logic are:

- shovelling capacity will always exceed trucking capacity, therefore, truck queuing is avoidable,
- proper blending of the coal may be of primary importance,

- distances travelled by coal haulers from pit exit to storage pile or crusher are fixed by pit design, only distances travelled in the pit and waste hauling distances are variables,
- satisfactory control of truck movement may be achieved if the required digging rate for each shovel is specified and if a logically correct decision is made for the dispatch of each truck so as to achieve the predetermined balance of material moved from the pit, and
- system must be flexible to account for breakdowns of trucks and shovels and unexpectedly difficult or easy digging conditions.

The question that may also arise is to how does one determine the feasibility of one or more types of dispatching approach. Several systems may be applicable to large scale mining operations but perhaps only one can be used at small mines. The model applicable to a majority of the mines must take into consideration all the differences between mines. In the case of modelling of truck haulage systems, the scope is particularly broad due to the variety of assignments of equipment.

The following list includes specifications required for the first phase of the truck/shovel modelling (8):

1. Loading equipment may be quite variable: shovels, loaders, continuous mining equipment, or bin. Data base of the equipment used for loading was developed in MINDAT model and may be used for the event-based model.
2. Time study data collected at the mine may be used, or the model may be feeded with real data continuously (Truck Management System), or mathematically derived values may be entered here.
3. Detailed haulage statistics per load basis, or averages, that will include quantity, material type and grade, will be made available to the model. Data, again, may be entered from time study data, by direct survey, or by using Truck Management System. Provision must be made here to interact later with a geological model, that will provide information on material grades mined in specified areas.

This information was specified previously (10 - 17) for each selected mine property, but will include as a minimum: FSI and volatiles for coal, bitumen content for oil sands, etc.

4. Field and shop repair will be distinguished separately, types of repair, duration and frequency of occurrences will be also calculated. This will be user specified information. For the start, up to ten items may be considered for evaluation.
5. Management and supervisory functions, deployment policies concerning refueling, tire overheating, shift changes, etc. will be incorporated.
6. Operating status assignments will include:
 - travelling loaded,
 - travelling empty,
 - being loaded,
 - waiting to be loaded,
 - active field or shop repairs,
 - waiting to dump,
 - dumping,
 - scheduled break,
 - being refueled,
 - box cleanup,
 - standby/idle,
 - waiting for repair,
 - being redeployed,
 - interference or delay by other equipment,
 - tire servicing, and
 - preventive maintenance.
7. Operator interaction must permit reassignment to another load site, place and remove from standby, start preventive maintenance, etc.

Hardware/Software Requirements.

The following items represent additional requirements of the truck/shovel computer based model:

1. Language used in modelling must be Vax Fortran 77, source being available for modification.
2. The model must run on Vax 11/750 using VMS. Any screen formatting for reporting or menus should either use the VMS screen management facility or a self-contained screen formatting package.
3. The graphics software portion must be self-contained or any required third party graphics package must be included.
4. CRT display should run on both VT-100 and VT-200 style terminals.
5. Graphics must run on the Tektronix 4109 terminal, or Vaxstation 100 terminal, using its intelligence, and on Calcomp plotter.
6. Digitizer input must be permitted through Calcomp digitizer.
7. Any high level simulation language used must be included.

The package provided must conform to the following volume requirements:

- | | |
|------------------------------|---------------------------|
| 1. No. of pits | - up to 5. |
| 2. No. of benches | - up to 5 within the pit. |
| 3. No. of sub-areas | - up to 20 within bench. |
| 4. No. of materials | - up to 10 types. |
| 5. No. of quality parameters | - up to 5. |
| 6. No. of dumps | - up to 10 concurrently. |
| 7. No. of lifts | - up to 3 in dump. |
| 8. No. of truck types | - up to 5. |

- 9. No. of shovel types - up to 10.
- 10. No. of blending areas at ROM - up to 5.
- 11. No. of loading conditions - up to 10.

Additional functional requirements are defined as:

1. Allow loading by shovels, backhoe attachment, loaders, and refuse bin, using single, double-sided loading, loading on two sides of a single truck (by two loaders). May also load coal from a pile backhoed from pit bottom.
2. Hauling to ROM (different areas for blending), topsoil piles, dumps, and road construction. May haul within pit for ramp construction or other purposes.
3. Spot and dump times are variable by the loader/truck. Load time variable by the loader/truck/material conditions.
4. Fuel consumption should be modelled.
5. Timing should be allowed for shovel moves.
6. No. of buckets for truck load and individual bucket weight should be modelled.
7. Included and defined should be fixed delays, fuelling, lubrication, cable moves, blasting delays, downtimes and reasons, scheduled PM's, and shift changes.
8. A scenario must be stored for future reference.
9. Data entry and option selection must be made simple through the use of menus.

10. Reporting must be optionally to CRT or printer with possibly different formats for each.
11. Permit expansion to the dispatch system.

Data Compatibility Requirements.

1. Input data required, such as equipment parameters, road networks, etc. must be introduced in GRRRL Short Range Planning formats by using predefined namelists and common blocks as enclosed in Appendix 1.
2. Actual data required must be derived from GRRRL production reporting system and on-board data acquisition systems. The format is not available at this time, but example of the type of data is found in Appendix 2.
3. Output data should be available for further site specific reporting and/or graphical display.

Model Concept.

In the design of the model, effective use must be made from three different data bases. First data base is the equipment data base that will include description of all the equipment available at the mine site and other equipment data as they became available from other users or from the manufacturer. Second data base will be provided by the mining company and will include all historical data on utilization of mining equipment, accounting policies, cost data, mine planning procedures, haulage routes, assignment policies, maintenance policies, or any other relevant information specified by the user. Third data base will include all real time study data provided on continuous basis by data management systems, maintenance data

collection systems, dispatch systems, or whatever data collection system is used at the studied mines. For present time, this requirement will be satisfied by accepting data from the OBDAS system installed at Gregg River Mine and from Modular Mining Dispatch system installed at Quintette Mine.

The above described data bases should preferably be installed on the same mainframe, for effectiveness and simple manipulation. When a mine data changes, only one amendment will be needed to update the base. The model must also take into account that at any given time, all mine departments may use the same data.

In general, two basic modules will form the model. First module will collect and evaluate the data (using continuous data supply by truck/shovel management system, or by manual entry), and will prepare data for further manipulation. The data (averages or statistical distributions) will be from specified period. For example, if the model will collect data for several years, data used in the model may be the averages/statistical distributions for last year or number of years. If the data are collected for months only, update of the data base will be on monthly basis. The user may also choose to select data by specifying time period. For example, user wants to have data for winter period only, or data from one pit only, he may select this option.

Second module will manipulate the data collected and evaluated by the first module. The module may be used as simulation model or for trucks dispatching. In first case, collected data will be used to predict events based on information supplied. In second case, truck will be directly manipulated by the model as stipulated by rules provided by the user.

The simulated activities at mine planning stage consider a mine that is in production. The mine planning model, loading and dumping times are determined by truck, shovel and dump point specifications. The simulation will use the same times for any event, irrespective of the number of times the event occurs (averages as determined by first model). An option may also be allowed to have the user stipulate that events have statistical distribution with means as calculated previously, and standard deviations as supplied by

user. This may be important at mines with only time study data available. The user may also select to incorporate breakdowns, relocation of equipment, changes in production requirement, etc.

In dispatching module, the user may simulate the dispatching of the trucks in automatic or semi-automatic approach. In completely automatic dispatching, the computer makes a decision where to send a truck immediately following the loading or dumping operation. In semi-automatic dispatching, each truck may be allocated to either a specific shovel or a specific dump point at the start of the simulation. The computer will then select, for each truck, either the loader or the dump, whichever has not been allocated by the user for this truck. All truck can also be given a fixed allocation to both a shovel and the dump. These facilities thus allow a comparison of both fully automatic and semi-automatic dispatching with fixed allocation. The fixed allocation is the standard procedure at most of the mines not using computerized dispatch system.

Interfacing with Model.

The model should be made interfaceable with user at any time during simulation process. The user may interrupt simulation, probably by hitting return key, and computer will display options to the user. These options may include proposed changes in truck allocation, breakdowns, delays planned or requested, repairs, shovel delays, etc., all delays will then be specified by the number of minutes of delays and start of the delay. It is also proposed to have two types of user interactions: first one for short term simulation, when the model will run for no more than 15 shifts (up to 12 hours duration each) and the delays will be specified in minutes, second one for long term simulation, when delay will be specified in shifts and fraction of shifts.

Second kind of interfacing will be through the data management or data collection system installed at the mine. Two types of data collection are in use at the present time: DISPATCH system at Quintette and OBDAS system at

Gregg River mines. In general, Dispatch and OBDAS systems will provide as minimum the following information (whether through operator input or by automatic collection):

- operator I.D. number/truck number,
- time of operator number entry,
- dumping of summary of previous operator activities,
- number of loads hauled,
- tonnage hauled,
- elements of cycle times,
- uphill/downhill driving,
- load distribution,
- weight shifting during loading and driving,
- stoppages, identification of breakdowns,
- dumping,
- driving empty load,
- warning signals and response to it during loading,
- summary of all events for shift or any larger period, and
- averages of data for any specified period.

The basic output from a truck monitoring system will have the following inputs:

- load/weighting sensors,
- transmission-directional monitor,
- dump swith,
- operator keypad,
- forward/reverse directional swith,
- distance sensor,
- inclinometer,
- fore-aft imbalance indicator,
- fuel sensor, and
- two spare channels for future installations.

The information may be feeded into central computer in four ways:

- direct tape unloading,
- non-volatile memory pack,
- radio telemetry, and
- infra-red telemetry.

The user may interact data transfer at anytime and may ask for analyses of the situation in the mine. The questions he may ask include:

1. Average number of loads/tonnes loaded per hour by each piece of loading equipment as well as time between the loads.
2. Tonnages loaded by particular pieces of loading equipment, tonnage hauled by particular trucks, and total tonnage hauled to each dump area as well as from each loading area.
3. Truck location.
4. Out of service times for all hauling/loading equipment.
5. Utilization of all equipment monitored and reasons for idle/delay times. If utilization is not satisfactory, the system will alert maintenance or operating personnel that utilization is not up to the projected level.
6. Delays in servicing of monitored equipment.
7. Averages of past production and prediction for future production data.
8. Change and assign equipment based on these predictions.

SYSTEM OPERATION

General.

The proposed computer model is designed in the way that it will compute current optimal route selections as mine conditions vary and assigns trucks to achieve maximum production for current mine operating conditions. Truck assignments attempt to enforce the route selection strategy while

considering current projected truck/shovel availability. Information necessary to measure current mine operating conditions is input directly by the data collection system installed at all trucks.

All load-haul-dump cycle transactions of the trucks and shovels are available by direct transfer of the data. A truck driver may also request the computer for direct assignment, computer decision may be overrun by dispatcher's command. The computer will evaluate applicable conditions and assign trucks to the location. The display of assigned location in the truck driver cabin will stay on until the next assignment is received. This reduces the possibility of the truck arriving at an incorrect destination.

At the completion of each load, the shovel operator will report the type of material in the load to the computer via the field panel in the shovel, or material may be made available as basic data in the computer via connection to the geological model. The computer at this stage informs the truck driver about his next dump assignment. Other necessary information the computer will receive includes data collected during driving, arrival at the dump location, loading at shovel times, weight of the load and its distribution, fuel consumption per kilometre and trip, tonne of material carried, delays, truck and shovel breakdowns, idle times. The computer system will therefore manage all truck assignments.

Use of the System.

The model will function properly, if all personnel associated with the project have defined responsibilities. The system, from operators viewpoint, illustrates typical shift operation under computer control as follows:

Pit Foreman:

Prior to shift start, the shift foreman enters "shift set-up" information on a terminal in his office. The interactive utility program issues a series of prompts that guides the foreman in making the operator equipment assignments and mine status changes for the coming shift. Examples in mine

status changes are shovel availability, dump availability and route hazard information. It is recognized, that mine status will not vary greatly from one shift to other, therefore status information is entered by exception. At completion of shift set-up, the information is printed (large bold type is preferred) and posted for the use of truck and shovel operators coming on shift.

Dispatcher:

The dispatcher is responsible for managing shift operation. He does this by monitoring system transactions and mine status information on terminal(s) in his office. The office should preferably be located in the tower or in the place to overview the entire pit, if this is possible. Best example may be the dispatch location at Lornex mine operation at Logan Lake in B.C. or Tyrone, N.Mexico pit. The shift set-up done by foreman is reviewed by the dispatcher. Corrections are entered, before the report is released. Transactions are instantly displayed on a CRT screen as they occur. This allow the dispatcher to monitor the entire operation. The system user may also inform the dispatcher by radio when his intervention is required. Arrival of a truck at a location other than the one to which the truck was dispatched may be treated as field error requiring dispatcher attention. In this example, the dispatcher signals that the displayed truck location is correct or that the truck driver must reenter his information. The dispatcher may also initiate system processing requests from a list of available options. Examples may include requests for truck assignments, mine status changes, and other specialized reports requested by any user. The dispatcher will maintain all dispatching functions with little or no intervention.

Truck Operator:

Truck operation under computerized dispatch system must be quite straight-forward process that can be learned in one day.

At the beginning of the shift, the truck driver requests an assignment and model designates an appropriate loading and dumping place. All assignments must be acknowledged by the driver. Proposed is also radio alarm, if acknowledgement is not acknowledged say after 10 seconds. All reportings is then done automatically. The driver is then asked to enter "end of shift" report by simply signing off. Breakdowns are reported to central dispatcher by radio and the dispatcher will enter data to the computer. The reason for delay is entered after report is received from maintenance foreman, or the foreman may also be authorized to enter data himself.

Shovel operator:

Shovel operator will enter his ID number at the beginning of the shift and sign off at the end of the shift. He may also report any delays, if instructed. It will also be desirable to have shovel operator trained to enter material he is loading, that may include simple statements, such as coal, partings, waste, or he may be trained to enter his location for identification of blending parameters. The location would be defined by surveyors and the shovel operator would simply enter ID numbers. He may also signal that he is moving to other area, so trucks could be reassigned by central dispatch to different dumping areas, to maintain blending requirement, and so on.

Another important feature of the computerized truck/shovel will be "Help" facility. This facility must be quite clearly defined. The explanation must be for any event specified, must be short and understandable. Three sets of "Help" facility are envisaged:

1. Help for Simulation module.

The model will have means to explain to the user all requested questions during simulation processes.

2. Help for Data entry/Data usage modules.

The provision in the model will enable user to request any information on data collection, either manual or automatic, will provide guidance on data entry, and will provide information on format of data output.

3. Help for Dispatch module.

This separate "Help" facility will be used by those who have opted for dispatching by the model. It will be used by dispatcher, truck or shovel operator, pit foreman, or mine manager, to answer questions related to dispatching, or will provide instruction on how to use and operate the model's real time data entry module.

Optimization Processes.

The proposed model will have several modules with "set up" optimization processes. The user will select one module, the one he wants to use in optimization experiment, at the beginning of the test. Only this module will then be accepted by the model, no other will be displayed. This is to simplify model operation. These modules are:

1. Optimal truck utilization.

Trucks are assigned continuously to shovels with minimum queuing time, the nearest available shovel being preferred. Trucks may be assigned to the places where this type of an assignment will not necessarily mean improvement in production, but the trucks will be kept working.

2. Optimal shovel utilization.

This optimization exercise will eliminate, or reduce, shovel waiting time. The queuing time will probably be increased.

3. Optimal production module.

This is the module that require advanced knowledge of system usage. The production may be optimized by combination of truck and shovel optimization modules. The production will then by optimized by combination of both optimization processes. The cost will not be considered.

4. Optimal blending module.

The blending of the material produced will take priority, all optimization processes will then be secondary.

5. Cost optimization module.

The module will provide estimate for most cost effective operation. It will not necessary provide optimum production, because only the cost per tonne (or m^3) of final product will be governing factor.

6. Combination of optimization modules.

The optimization modules may be to some extend combined to achieve best utilization of equipment and at same time provide optimum blend and maximized production at minimum cost.

Separate exercises may be also carried by the model to provide user with the optimal route selection. The optimal route is defined as the set of routes that requires the minimum number of trucks to achieve a desired production level. Because sometimes the operator in complex mine is faced with several routes to select from, the optimal route may or may not be specified, but a set of possible routes may be selected instead. It is recommended, that the set of all possible routes be displayed to the user visually for inspection. The reason for selection of all routes may also be displayed to establish priorities by the user that requested this information. Route selection is a dynamic process that must be periodically updated to reflect continuous changes in mine operating parameters. Examples of changes which necessitate route selection updates include shovel breakdowns, shovel moves, shovel delays, route hazards, changes in truck travel times

and shovel digging rates, dumps opening and closing, and material change. The route selection may therefore be viewed as a static or steady-state flow pattern that is updated as frequently as changes in mine operating conditions dictate. The changes may also be introduced to the model during simulation of mining conditions, for planning of short term events, or to prepare procedures for emergencies.

Model Scenarios.

A common feature of a surface coal mine in Canada is the continual change of haul roads. Some roads, defined as main haulages, are not changing for some time, compared to mine access roads, in-pit roads, ramps, etc. Proposed or planned haul roads extensions, re-routing of vehicles, intersection points and the like, are some aspects a planning engineer examines in order to produce a working plan of a mine. They are other considerations in an open-cut mine which require careful study. These may include operating details on a day-to-day basis. In order to produce an integrated plan, all these features need to be identified and included in an overall design. In the proposed simulation model, an attempt is made to incorporate not only the main features of an open cut mine, but also details of operations often too tedious to warrant consideration. These details may include the following separate exercises:

Inputs:

- details of haulroads and section of haulroads,
- specification of truck types, etc.,
- speed factors,
- loading and dumping times for shovels,
- dumping points for each truck type,
- statistical distribution or unique values used,
- gear or torque specifications,
- equipment numbers, names, types, assigned locations,
- capacities,

- fixed and variable unit costs,
- diesel-electric, conventional, trolley assist or not,
- types and specification of materials,
- shift length,
- total simulation period,
- numbers of each type of units,
- maximum speeds for loaded or empty trucks,
- meal breaks,
- management policies re. shift changes, meal breaks, breakdowns,
- truck and shovels relocations policies,
- algorithmus to construct frequency curves for random sampling, and
- list of observations of times for all types of events simulated.

Processing:

- selection of haul and load/dump times according to unique values,
- selection of events according to a statistical distribution,
- shift start up and finish,
- activation of shovels and dump points for truck processing,
- closing down of shovels, dump points,
- relocation of trucks to minimize queuing,
- tracing of trucks in the field,
- simulate computer dispatch,
- monitoring of end-of-the shift approaches to identify opportune times for sending trucks back to the base, if identified,
- selecting shovels or dump points for queuing times minimization,
- conventional allocation of specific trucks to specific shovels,
- full compilation of statistics,
- selection of all event times according to random samples, and
- draw the samples from cumulative frequency curves.

Output:

- total loading and dumping times,
- total distance travelled,
- haul distance for each truck per shift,

- total down times and queuing times for all shovels and trucks,
- utilization and availabilities for all units,
- calculation of fixed and variable costs,
- total quantities of material carried, and
- quantities carried between all combination points.

The model simulation will determine the disposition of all equipment at any given time. Breakdowns for trucks and shovels are considered and alternative allocations due to such changes are implemented. A record of machine inventory, location, specification ,etc., should be maintained and be easily recoverable from the model for any specified period of time.

Reporting.

The reporting is the program simulation output that is proposed to be in three forms:

- display,
- automatic reporting, and
- requested reporting.

The displays may also be specified as requested or automatic. This may be a feature in the program, if requested by the user. At present time, several potential users were interested in automatic display only, when the dispatch system is used. The displays are proposed to be shown on screen by default, with the objective to present the basic information on the state of the mining operations. The activity displayed may include:

- truck location for each shovel,
- shovel production,
- cumulative shovel production,
- number of operating trucks,
- trucks down and on standby,

- shovels down and on standby,
- date and time of the day,
- list of warning events,
- over/under trucking for locked hauls, and
- shovel statistics, such as:
 - . average load times per truck type,
 - . average cycle time,
 - . average queue time per cycle, and
 - . average idle time per cycle.

The automatic reporting will as a minimum include:

- basic shovel or truck production,
- efficiency report,
- production and blends reports,
- target parameters and percentage deviation,
- blend history,
- record of all warnings and responses to it,
- shift reports (or hourly, daily, no schedule reports),
- crusher report on material delivered,
- dumps report,
- shovel production,
- truck by type or individual production and delay summary, and
- dispatching reports.

Requested reporting may be added to the automatic reporting and produced together or requested in addition to the automatic reporting at anytime. These reports are produced on immediate request and are expected to show:

- shovel and truck production,
- efficiency reports,
- blending history,
- truck events by selection,

- log of all equipment status, and
- contents of screen.

Other reports may be generated that are specific to the mining company that uses the model. The model will therefore have a provision in its structure for these additional requests.

Examples of the additional reports may be any results of optimization studies, simulation studies, training exercises, and so on. The optimal policy identifier, that provide set of policies that satisfy user of final product, while maximizing production in any specified period, may be another example.

Warning Systems.

The provision for warning, recording of warned events and response to the warned events, must be incorporated in the model. This warning system will come from the field, when special attention to such happening is needed from operator, dispatcher, pit foreman, mine manager. Some warnings will be conveyed directly to the person concerned, others will be sent to all. The specific warnings, for example, are proposed to be used as part of the truck management and data collection system, when truck driver and shovel operator are warned that truck is full, or close to be full, or weight is not properly distributed at the truck. The model will provide the requested warning for the following events:

- help requested by driver,
- truck stopped too long, no reason identified,
- truck not registered at check point as expected,
- truck reassignment by dispatcher,
- change of truck status,
- change in status not acknowledged by operator,
- cab display of weight on truck failed,
- communication failed,

- communication restored,
- change of shovel operating status by dispatcher,
- initialize data to start up system,
- after power failure,
- system fault indication,
- truck at wrong shovel or dump,
- truck travel too long,
- truck speeding,
- blend out of range,
- truck on wrong route,
- vital sign warning,
- hourly production from the shovel is below established minimum,
- stop/go sensor failure,
- odometer failure, and
- dump close to capacity.

AUTOMATIC VEHICLE LOCATION

Problem Definition.

A significant problem in surface mines is loss of control of hauling trucks due to bad weather or wrong vehicle location, unknown to dispatcher. The trucks are assigned to various loading or dumping points at the mine, but are lost because of poor visibility, lack of knowledge of mine haulage system, or so on. During inclement weather, when visibility at some mines in the mountain region drops, mine production stops. This results in lost production that may be as high as eleven working days per year (17). During periods of reduced visibility, trucks are forced to slow down, reducing production to unacceptable level and creating problems in operation scheduling. Vehicles lost to the dispatcher, or vehicles having poor visibility, are then operating at reduced safety level and may create hazard conditions at the mine.

It is proposed to develop an independent system of vehicle positioning that is not dependent on any haulage 'marking' system. The vehicles must be able to be located at will. The dispatcher must be able to provide guidance to the operator, or provide warning to the operator about obstacles in front of him. The operator may also be informed about his location and he should be guided to his next assignment by simple graphical display in his cab. Warning should be provided in case of emergency in the truck path.

Components of the System.

An Automatic Vehicle Location System has been defined and proposed for mining application (18, 19, 20). The system hardware includes computer, input-output and CRT facilities, storage medium, positioning device and a data link. The software contain control programs, various databases, interfaces, and input files. The system provide a real-time plot on the CRT screen of all vehicles in operation. The knowledge of vehicle location, their positioning and direction, will provide basic input for dispatching and allocation of vehicles in an optimal manner.

It is proposed to use a positioning system, such as Trimble 4000S GPS receiver and a terrestrial ranging system, like a microwave transponder system (20), for 3-D positioning in a dynamic mode. Using two Trimble receivers, relative positions of off-highway vehicles can be obtained to an accuracy of a few decimetres. The microwave transponders can also provide 3-D positioning in a dynamic mode. One master station in the vehicle can interrogate three or more fixed-transponder stations simultaneously to provide 3-D coverage over a defined area. Several mine vehicles can be positioned at the same time using the same transponders. The maximum number is dependent upon the particular system.

Functional Concept.

In addition to the positioning component of the system, route map and digital terrain model must be developed as an integral part of the system. A route digital map (in vector digitizing) is proposed to be used for both vehicle positioning and real-time optimization and scheduling. The scheduling processes will assign vehicles to loading or dumping points, optimization processes will select optimum route for vehicles to follow. The route will then be display to the truck operator, giving him its vehicle location and direction of travel. It will inform him about next turn, stoppage, obstacles in front of him, or any other relevant information.

The computer database of the functional system is expected to be structured on a relational model of a route network where roads are links and stations and facilities are nodes. The choice of database model saves a significant amount of storage of the main computer and may be readily updated. The database is expected to be also used as the main framework in determining real time, optimal scheduling and allocation. Dynamic scheduling is expected of the system, including changing parameters of the haulage network, changes in rolling resistance of the road surface in relation to weather, etc., are considered.

The topography of the mining site is characterized by a digital terrain model. The model will complete the map data base by adding the height dimension. The dispatcher then can plan the routes in relation to grade of the road and keep track hauled volumes of the material. All this information can be stored in a data base and further calculations with volume per haul and hauling scheduling can be done. The system then provide additional statistics as defined by user, for example volumes in time, volumes for blending, etc. The model must have provision to be updated from time to time.

Integration into Event-based Model.

The proposed vehicle positioning system will provide valuable information to mine management and engineering personnel. With the knowledge of vehicle location, an accurate mine model is complete. The mine production may be efficiently maintained, mine equipment is optimized, future events

are readily predicted, mine operation safety improves. A total mine management system will then provide optimal allocation and scheduling of machines and manpower at the mine.

The mine modelling system must be therefore able to run three ways: by using average data to simulate future events, by using random data to predict event distribution and frequency, and by using real time data as collected by the vehicle management system or vehicle positioning system. The data transferred by the vehicle positioning system will include at least co-ordinates of the vehicles, elevation, meeting points, various road restrictions, warning provision for obstacles ahead, other management criteria for safe and efficient operation. Means of incorporating these provisions into the overall system are not known at the present time.

CONCLUSION

An event-based model of the truck/shovel operation for surface coal mines in Western Canada is proposed. The model, general in its architecture, is expected to be used for specific applications at any coal mine that will co-operate on its development. The model is proposed to serve as a simulation tool, a base for dispatch systems and for training purposes. This proposal is preliminary in its nature, additional information will be added after the proposal is reviewed by the industry.

The proposal reviews general steps in simulation, data collection and evaluation systems, and provide discussion on model development. It is proposed, that the model accept data entry using manual or automated data transfer systems, such as Dispatch or Obdas data management and collection systems. The need and strategy of the modelling is presented for comments, requirements are formulated as seen at present. The proposed model concept and way of interfacing with the model is outlined. The system operation as seen through use as a simulation or dispatching tool is described. The proposal also contains examples of optimization processes, model scenarios

by using input, processing and output functions. Types of reporting and provision for warning systems are also included.

The proposed computer simulation is general and therefore complex. Before work commences on such a complex model all parties must consider whether a suite of simpler models would be more appropriate. For example, a real time dispatching system could use a very simple model where the truck cycle is divided into relative few segments, where time distribution is calculated by the recent history as reported over the last few hours by an on-board data collection system. By using real data, many of the complexities of general simulation programs become redundant. The sophistication and accuracy of the model comes from the reality of the input data rather than from complex and sophisticated simulations based on stale or questionable data.

In the present economic climate emphasis must be placed on economic performance of existing equipment in use in current mines. Analysts and programmers are well advised to seriously consider computer based operating aids that provide rapid response to dynamic conditions in producing mine environments.

In the past real time equipment performance data was not available. As that type of information becomes available the challenge becomes how best to integrate real time equipment operating and performance data, real time vehicle location data and mine defined dispatching policies into computer based operating and management systems that provide real time assistance. Complex computer simulation programs may in fact impede that goal.

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